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# Arsenic, iron and chloride in drinking water at primary school, Satkhira, Bangladesh

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ABSTRACT

Safe water is essential for all living things. Globally, a good fraction of school-aged children, especially in the developing countries children are suffering from several water-borne diseases. In this study, potable water supplies for primary school children were examined at Satkhira district, Bangladesh to ensure arsenic-free drinking water. In 240 randomly selected tube wells water of the primary schools were monitored from the seven Upazilas in Satkhira district, Bangladesh. The metal content, especially arsenic and iron in the tube wells water were analyzed by atomic absorption spectroscopy. Results indicate that arsenic content was exceeded the World Health Organization (WHO) guideline value maximum contaminated level (10 μg/L) in 49% of the tube wells water and reached up to 167.9 μg/L. The level of iron and chloride content was in the tube wells water from 10.01 to 13479.6 μg/L and 29.3–9987.01 mg/L, respectively. The 49% tube wells (118 out of 240) chloride and 45% tube wells (110 out of 240) iron content were exceeded by the Drinking Water Quality Standards of Bangladesh. The drinking water parameters especially arsenic at Satkhira district did not meet the requirement of the WHO drinking water quality guideline or the Drinking Water Quality Standards of Bangladesh. The obtained data were treated for estimating chronic daily intake (CDI) and Hazard Quotient (HQ). The HQ values were > 1 for arsenic in the tube wells water of seven Upazilas at Satkhira district. Lifetime drinking of arsenic-contaminated water may trigger cancer risk to the human health.

## 1. Introduction

Water is life. All living things require water as the principal medium and solvent of their metabolic activities. Nonetheless, pure water does not exist in the environment. Freshwater is available for human consumption, which derives from the rivers, lakes, tube wells (TWs), ponds and subsurface aquifers. These sources account for only one percent (1%) of all water on the earth; one-third of the world's population use groundwater for the drinking and other household purposes (Nickson et al., 2005). Impurities of trace elements in the surface and groundwater are the primary concern in human health, especially for the children. Hence, drinking water monitoring for the trace elements including their physicochemical parameters is very important.

A good fraction of the world's population is facing the shortage of water, and day-by-day its demand is increasing. Increasing urbanization and industrialization are blaming the amplified level of trace metals, particularly heavy metals in the waterways (Singh et al., 2011). Drinking water sources are continuously contaminated by the natural and human activities (Kinniburgh and Kosmus, 2002; Roussel et al., 2000). The contaminants e.g., bacteria, virus, heavy metals, nitrates, and salt have found their way into water supplies due to insufficient treatment and disposal of waste, industrial releases as well as over-use of the limited water resources (Singh and Mosley, 2003). Surface and groundwater are the significant water resources for the drinking, bathing, irrigation and household purpose for the coastal people of Bangladesh (Palaniappan et al., 2010). Bangladesh has been highlighted that arsenic level in the groundwater is found to be causing harmful effect on human (Anawara et al., 2002).

Arsenic (As) content in drinking water has an adverse effect on the children between the ages of 5–10 years. Fazal et al. (2001) reported that arsenite As (III) is 60 times more toxic than arsenate As (V). As(III) binds to sulfhydryl (−SH) groups that have the broad toxicity (NRC, 2001). The sulfur-containing protein can react with As (III) to form products that may cause biological body malfunction (Wang and Wai, 2004). As(III) impairs the function of many proteins (Kumaresan and Riyazuddin, 2001). People of As exposure might develop damages for the higher neurological functions (Rodrıguez et al., 2003). Children who are exposed to As show lessened learning and memory, sleep

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disturbances, abnormality and hearing problem (Yadav et al., 2011).

Worldwide, in the developing countries, 46% of school-aged children are affected by anaemia (UNICEF/UNU/WHO/MI Technical Workshop 1998). Serious anaemia causes shortcoming of knowledge and often-permanent significance to the cognitive developments of the young children (Beinner et al., 2005). Iron (Fe) plays a dynamic role in oxygen utilization and energy requirements in the cells. Deficiency of Fe steals the vitality of the young and old and impairs the cognitive development of children (UNICEF/UNU/WHO/MI Technical Workshop 1998). In natural fresh water, Fe is found at the level of 0.5–50 mg/L, while the established Provisional Maximum Tolerable Daily Intake (PMTDI) is 0.8 mg/kg of body weight, except for instances when Fe supplements need to be taken during pregnancy or for the specific clinical requirements (WHO, 2011).

Chloride is present in the groundwater, which originates from the various sources e.g., weathering, leaching from the sedimentary rocks and infiltration of the seawater, etc. (Rahman et al., 2016). It is distributed in nature as sodium chloride (NaCl), potassium chloride (KCl), and calcium chloride ($CaCl_2$) salts. Chloride content in water at the level of 250–500 mg/L produces salty taste (Trivedy and Goel, 1984).

Children are the future of the nation. Safe water is essential for the children's development processes. It permits children to enjoy indispensable hygiene to remain in good health. The presence of safe water in the schools contributes significantly to the realization of the right to education. Right education will contribute to the greater social development ultimately to increase the economic development of the country. Children learning can be seriously restricted if the school's authorities don't have the facility to provide safe drinking water and sanitary toilets. Even many girls do not attend school due to the lack of proper toilets for the girls. Hence, it is an urgent need especially for the developing country to ensure safe drinking water for the children.

In this study, drinking water of the primary school at Satkhira district, Bangladesh was monitored to ensure safe drinking water for the school children. The As and Fe analysis were performed by the atomic absorption spectroscopy (AAS) because of its reliability. The As, Fe, and chloride content of the tube wells (TWs) water were determined following by the APHA (2012) standard analytical methods. The obtained data were treated for the human health risk assessment as well as comply with the national and international drinking water standards.

## 2. Materials and methods

### 2.1. Study area

The study was carried out at Satkhira district (Fig. 1), located in the southwestern part of Bangladesh. The district has an area of 3817.29 $km^2$ which is bordered to the north by Jessore district, on the south by the Bay of Bengal, to the east by Khulna district, and to the west by 24 Pargana district of West Bengal, India. The district consists of seven Upazilas (former thana used for administrative purposes) namely: Satkhira proper, Tala, Assasuni, Kalaroa, Kaliganj, Shyamnagar, and Debhata.

### 2.2. Sampling

The drinking water samples were collected from the 240 (two hundred and forty) randomly selected tube wells (TWs) of primary schools from the seven Upazilas at Satkhira district, Bangladesh. Three samples were collected from each sampling points. Two samples were taken from each sampling points in the high-density polyethylene (HDPE) bottles for As and Fe analysis. Before sampling, the container was washed with detergents, followed by tap water and finally several times with distilled water. Another container of water samples was collected in the HDPE bottles from each point for chloride determination without using any preservatives. Considering the fact that physical, chemical and/or biochemical reactions might take place in the sample container, which may lead to change in the intrinsic quality of the sample during collection for analysis; therefore, for the analysis of As, and Fe, water samples were filtrated through the Millipore cellulose membrane (0.45 μm) in the HDPE bottles acidified with 1% nitric acid. The collected samples were identified as SB01 to SB240. All samples were kept in the refrigerator at 4 °C until to complete the experiment. GPS meter (Garmin eTrex 10) was used for the location of sampling points. Chronologically, sampling points of the seven Upazilas are inserted in Tables 1–7.

### 2.3. Reagents

All stock solutions were prepared from the analytical reagents (AR). Freshly prepared double deionized distilled water was used in all experiments. The As and Fe standard solutions were procured from the Fluka-Analytical, Switzerland. A 20% potassium iodide (Sigma-Aldrich, USA) solution was used to reduce the As(V) to As(III). Arsenic trihydride ($AsH_3$) generation was performed with 5M HCl (Sigma-Aldrich, USA) and 0.6% sodium borohydride solution (Sigma-Aldrich, USA) as a reducing agent.

#### 2.3.1. Analysis of TWs water

The quality of TWs water samples was measured regarding As, Fe, and chloride. All the analysis were conducted following the standard methods of APHA (2012).

#### 2.3.2. Determination of As, and Fe

The As content in the TWs water was analyzed by the atomic absorption spectrophotometric APHA (2012) method. At first, the calibration curve was made using the working standard solutions from the different concentrations of the certified reference materials (CRM). Then, the metal ions of the sample were found from the calibration curve. The As was measured by the hydride vapour generation (HVG) method, where argon was used as carrier gas and recordings were performed at the wavelength of 193.7 nm. The Fe content was measured using a direct flame (air-acetylene) at the wavelength of 248.3 nm. Mean and standard deviations were calculated from the triplicate measurement of each sample. Errors were calculated to ± 5%. Instrumental analytical conditions for the analysis of the heavy metals are given in Table 8.

#### 2.3.3. Determination of chloride content

Chloride content in the TWs water was measured by the APHA standard argentometric method. A 100 mL water sample was taken in a conical flask and pH was adjusted in the range of 7–10. After that, 1.0 mL potassium chromate ($K_2CrO_4$) indicator was pipetted. Then, the solution was titrated with silver nitrate as titrant (0.0141N) to a pinkish yellow endpoint. The titrant was standardized by the sodium chloride (0.0141 N) solution.

### 2.4. Human health risk assessment

Human health risk assessment is the assessment of the population's health to what extent would be at risk through drinking of As-contaminated water. The health risk is considered for both the non-carcinogenic and carcinogenic exposure arising from the intake of As. The USEPA recommended method is used for the estimation of health risk assessment. The human non-carcinogenic health risk is assessed on the basis of chronic daily intake (CDI) of metals and hazard quotient (HQ) for both the adults and children. Also, carcinogenic risk (CR) was calculated for As since only As has oral slope factor value among the investigated parameters.

CDI was calculated according to the modified equation (i) of Kumar et al. (2016):

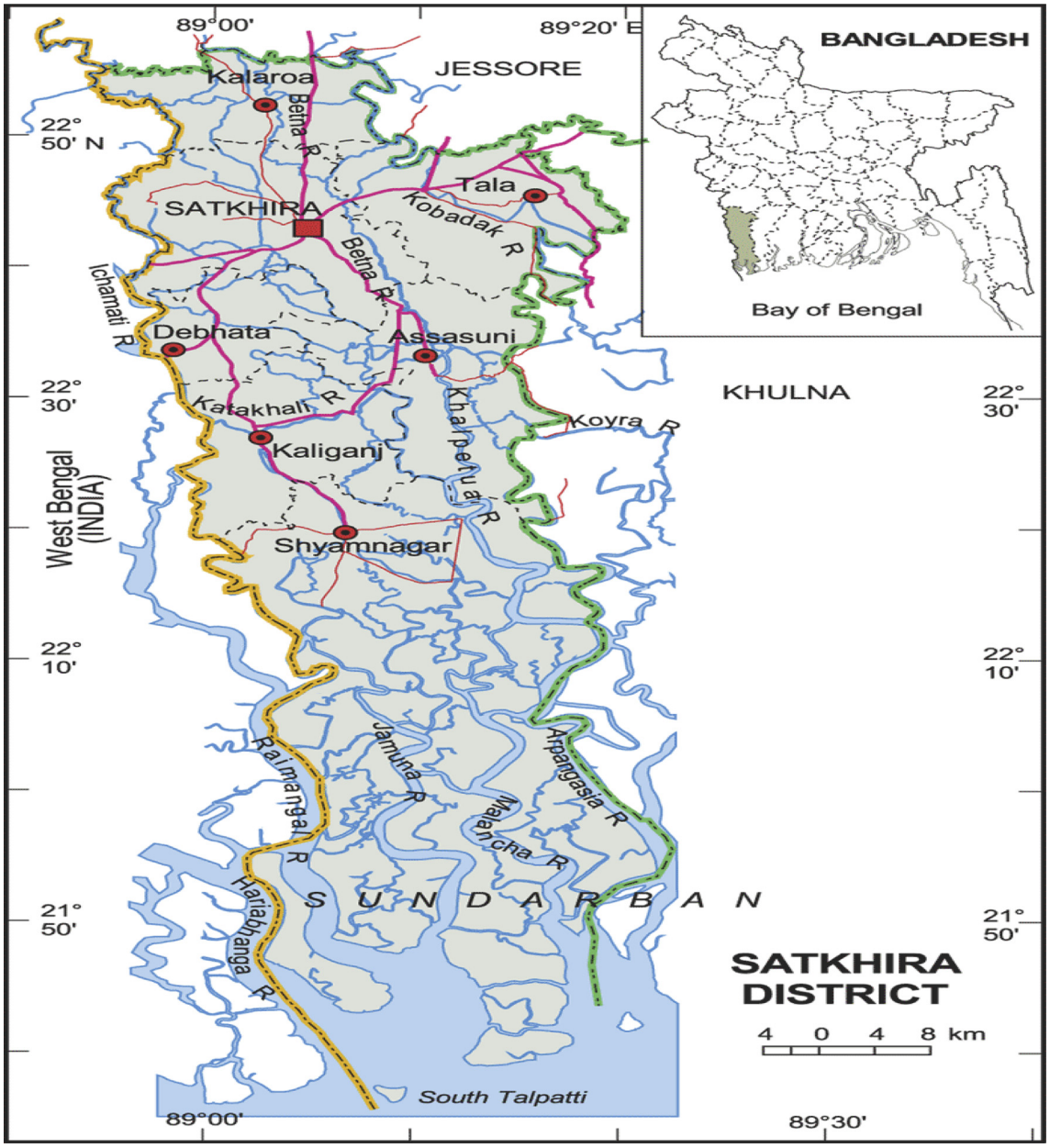


**Fig. 1.** Sampling location of the seven Upazilas with red marked at Satkhira district. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

$$CDI = \frac{(C \times IR_{water})}{BW} \quad (i)$$

Where C is the concentration of metal in water (μg/L), $IR_{water}$ is the ingestion rate of water (1.5 L/day), BW is the body weight (body weight of children is approximately 31.97 kg) (NCHS, 2000). The $IR_{water}$ was confirmed during the field survey asking the school authorities/teachers of 240 primary schools and confirmed using a calibrated glass of 100 mL, 200 mL, and 500 mL.

HQ was estimated from the following equation (USEPA, 2002):

$$HI = \frac{CDI}{RfD_o} \quad (ii)$$

Here $RfD_o$ is the oral reference dose (mg/kg/day). The $RfD_o$ was 0.3 μg/kg/day for As (USEPA, 2015). When, the value of HQ < 1, the exposed population is safe from the certain harmful effects of that trace metals. If HQ > 1, it may pose adverse health effects on the exposed population.

Hazard Index (HI) is the sum of HQ of the individual trace metals. It is expressed as:

$$HI = HQ_{metal} \quad (iii)$$

The CR is considered by means of the subsequent formula (Patrick, 1994):

$$CR = CDI \times SF \quad (iv)$$

SF is the oral slope factor (μg/kg body weight/day) and for As the value of SF is 0.0015 μg/kg/day (USEPA, 2015).

## 3. Results and discussion

### 3.1. Physical appearance of TWs water

Instantly, the physical appearance of the TWs water was observed in the daylight by the bare eye, and it was clear without sand.

**Table 1**
Sampling points, arsenic, iron and chloride content of Tube wells water at Satkhira proper, Bangladesh.

| ID | Location | Sampling points | Type | Depth (m) | Fe (μg/L) | As (μg/L) | Cl (mg/L) |
|---|---|---|---|---|---|---|---|
| SB01 | Batkekhali GPS | N:22°41′41″ E:89°04′29″ | DTW | 195.12 | 679.7 ± 0.8 | 4.02 ± 0.01 | 267.4 ± 1.03 |
| SB02 | Itagacha Adarsha GPS | N:22°42′17″ E:89°03′52″ | DTW | 225.61 | 740.04 ± 0.3 | 29.4 ± 0.04 | 275.4 ± 1.3 |
| SB03 | Rasul Pur GPS | N:22°43′50″ E:89°04′04″ | DTW | 213.41 | 1139.6 ± 0.31 | 18.07 ± 0.1 | 1168.07 ± 1.02 |
| SB04 | Mach Khola Poura GPS | N:22°42′39″ E:89°05′54″ | DTW | 189.02 | 2910.01 ± 0.5 | 92.9 ± 0.3 | 234.9 ± 0.9 |
| SB05 | Mach Khola GPS | N:22°42′41″ E:89°06′33″ | DTW | 164.63 | 4319.7 ± 0.07 | 34.05 ± 0.02 | 712.05 ± 0.8 |
| SB06 | Per Mach Khola GPS | N:22°42′45″ E:89°06′48″ | DTW | 176.83 | 4559.8 ± 0.31 | 76.3 ± 0.1 | 85.01 ± 0.7 |
| SB07 | Shalley GPS | N:22°43′20″ E:89°06′14″ | DTW | 176.83 | 1110.01 ± 0.4 | 67.9 ± 0.3 | 100.04 ± 0.5 |
| SB08 | Uttar Fingri GPS | N:22°37′29″ E:89°06′11″ | DTW | 140.24 | 529.7 ± 0.07 | 76.3 ± 0.07 | 414.6 ± 0.4 |
| SB09 | Sultanpur Polli GPS | N:22°38′00″ E:89°07′19″ | DTW | 176.83 | 2279.8 ± 0.5 | 22.01 ± 0.01 | 1266.3 ± 1.01 |
| SB10 | Jahanabaj GPS | N:22°39′45″ E:89°07′05″ | DTW | 158.54 | 290.05 ± 0.08 | 5.9 ± 0.01 | 694.8 ± 0.8 |
| SB11 | Ramchandrapur GPS | N:22°41′17″ E:89°05′45″ | DTW | 201.22 | 539.6 ± 0.41 | 77.03 ± 0.1 | 142.07 ± 0.6 |
| SB12 | Zeala GPS | N:22°41′51″ E:89°06′34″ | DTW | 170.73 | 639.5 ± 0.21 | 86.3 ± 0.2 | 105.02 ± 0.5 |
| SB13 | Bansghata GPS | N:22°45′26″ E:89°02′31″ | DTW | 173.78 | 159.6 ± 0.03 | 6.05 ± 0.04 | 1895.7 ± 0.4 |
| SB14 | Ramerdanga GPS | N:22°47′57″ E:89°01′03″ | DTW | 237.80 | 139.7 ± 0.04 | 3.8 ± 0.01 | 1968.04 ± 1.3 |
| SB15 | Panch Rokhi GPS | N:22°48′13″ E:89°00′09″ | DTW | 170.73 | 189.9 ± 0.02 | 2.01 ± 0.02 | 664.9 ± 1.01 |
| SB16 | Aich Para GPS | N:22°49′01″ E:88°59′56″ | DTW | 195.12 | 10.01 ± 0.1 | 15.04 ± 0.1 | 280.07 ± 0.6 |
| SB17 | Bow Khola GPS | N:22°46′03″ E:88°58′34″ | DTW | 207.32 | 229.6 ± 0.07 | 22.6 ± 0.04 | 214.8 ± 0.5 |
| SB18 | Kashempur GPS | N:22°44′17″ E:89°03′18″ | DTW | 210.37 | 110.4 ± .01 | 2.03 ± 0.01 | 674.9 ± 0.4 |
| SB19 | Silver Jubilee GPS | N:22°42′41″ E:89°04′29″ | DTW | 208.32 | 559.6 ± 0.05 | 1.04 ± 0.02 | 835.07 ± 0.3 |
| SB20 | Katia DasPara GPS | N:22°43′50″ E:89°04′40″ | DTW | 210.46 | 760.3 ± 0.23 | 1.01 ± 0.01 | 1127.6 ± 0.8 |
| SB21 | Dakkhin Kushkhali GPS | N:22°46′15″ E:88°56′37″ | DTW | 196.25 | 479.6 ± 0.06 | 10.9 ± 0.03 | 180.07 ± 0.4 |
| SB22 | Hazipur GPS | N:22°48′14″ E:89°02′56″ | SST | 21.00 | 6110.3 ± 0.6 | 46.07 ± 0.1 | 68.05 ± 0.7 |
| SB23 | Amtala Basabati GPS | N: 22°47′55″ E: 89°04′10″ | SST | 21.00 | 5030.1 ± 0.8 | 5.03 ± 0.01 | 535.9 ± 0.4 |
| SB24 | Katthaltala GPS | N:22°47′28″ E:89°04′33″ | SST | 21.00 | 6579.7 ± 0.6 | 20.6 ± 0.07 | 29.3 ± 0.6 |
| SB25 | Gobordari GPS | N:22°36′43″ E:89°07′22″ | SST | 21.00 | 2069.5 ± 0.4 | 41.07 ± 0.04 | 233.07 ± 0.3 |
| SB26 | Tujalpur GPS | N:22°47′34″ E:89°02′40″ | SST | 21.00 | 7109.6 ± 0.7 | 23.7 ± 0.3 | 67.1 ± 0.2 |
| SB27 | Baliadanga GPS | N:22°38′25″ E:89°00′05″ | DTW | 21.00 | 10.1 ± 0.05 | 15.03 ± 0.01 | 1114.4 ± 1.3 |
| SB28 | Shusilgati GPS | N:22°33′39″ E:88°57′18″ | DTW | 21.00 | 549.8 ± 0.3 | 18.04 ± 0.04 | 233.06 ± 0.3 |
| SB29 | Budhordanga Shivpur Sonarbangla GPS | N:22°44′41″ E:88°59′58″ | DTW | 207.50 | 10.01 ± 0.06 | 16.07 ± 0.1 | 913.9 ± 0.5 |
| SB30 | Chanka GPS | N:22°43′20″ E:88°58′24″ | DTW | 214.00 | 29.6 ± 0.07 | 3.03 ± 0.02 | 336.3 ± 0.07 |
| SB31 | Panchani GPS | N:22°41′37″ E:89°01′32″ | DTW | 152.00 | 340.4 ± 0.04 | 2.01 ± 0.01 | 243.04 ± 0.03 |
| SB32 | Nabajug Shikkha Sopan GPS | N:22°41′27″ E:89°05′16″ | DTW | 206.50 | 549.6 ± 0.2 | 15.05 ± 0.06 | 244.8 ± 0.3 |
| SB33 | Shohid Khokan Smrity GPS | N:22°44′02″ E:89°01′48″ | DTW | 187.50 | 1760.0 ± 0.6 | 1.03 ± 0.01 | 720.7 ± 0.6 |
| SB34 | Alipur Dighirpar GPS | N:22°40′48″ E:89°01′19″ | DTW | 134.14 | 1429.8 ± 0.5 | 1.02 ± 0.01 | 523.06 ± 0.2 |
| SB35 | Mirgidanga GPS | N:22°45′22″ E:88°57′55″ | DTW | 260.67 | 730.4 ± 0.07 | 1.07 ± 0.02 | 243.7 ± 0.1 |
| SB36 | Bhomra GPS | N:22°40′08″ E:88°57′39″ | DTW | 192.07 | 220.1 ± 0.04 | 1.04 ± 0.01 | 325.04 ± 0.5 |
| SB37 | Bhabanipur GPS | N:22°47′27″ E:88°57′36″ | DTW | 215.00 | 109.8 ± 0.02 | 1.05 ± 0.02 | 932.08 ± 0.7 |
| SB38 | Baluigacha GPS | N: 22°40′41″ E:89°07′33″ | DTW | 198.00 | 1640.4 ± 0.3 | 14.7 ± 0.05 | 957.8 ± 0.5 |
| SB39 | Shohid Kajol Smrity Paschim Jordia GPS | N:22°36′02″ E:89°07′18″ | DTW | 198.00 | 849.3 ± 0.4 | 9.3 ± 0.01 | 945.03 ± 0.3 |
| SB40 | Bhadra GPS | N:22°46′20″ E:88°58′42″ | DTW | 200.00 | 180.01 ± 0.05 | 1.03 ± 0.02 | 512.8 ± 0.4 |
| SB41 | Rajnagar GPS | N:22°46′16″ E:89°05′00″ | DTW | 198.17 | 1560.07 ± 0.4 | 1.05 ± 0.03 | 769.03 ± 0.07 |
| SB42 | Nabakhali Sardarpara GPS | N:22°44′46″ E:89°01′49″ | DTW | 189.00 | 1539.6 ± 0.2 | 2.08 ± 0.02 | 759.01 ± 0.4 |
| SB43 | Pathorghata GPS | N:22°49′20″ E:89°02′44″ | SST | 21.00 | 4309.8 ± 0.5 | 20.9 ± 0.04 | 107.9 ± 0.3 |
| SB44 | Roypur GPS | N:22°49′04″ E:89°05′09 | SST | 21.00 | 4870.4 ± 0.3 | 18.7 ± 0.1 | 48.3 ± 0.04 |
| SB45 | Dakkhin Debnagar GPS | N:22°45′13″ E:89°04′16″ | SST | 21.00 | 1919.8 ± 0.07 | 38.03 ± 0.2 | 39.7 ± 0.02 |
| SB46 | Rajbari R. H. R. GPS | N:22°47′57″ E:89°02′52″ | SST | 21.00 | 13479.6 ± 0.5 | 61.7 ± 0.08 | 181.6 ± 0.07 |
| SB47 | Mograjpur GPS | N:22°45′23″ E:89°03′33″ | SST | 21.00 | 760.07 ± 0.3 | 29.04 ± 0.04 | 48.03 ± 0.2 |
| SB48 | Gobordari GPS | N:22°36′43″ E:89°07′22″ | SST | 21.00 | 850.4 ± 0.07 | 1.04 ± 0.02 | 533.9 ± 0.7 |
| SB49 | Hawalkhali GPS | N:22°48′42″ E:88°59′18″ | DTW | 220.26 | 3209.6 ± 0.2 | 21.01 ± 0.03 | 219.05 ± 0.3 |
| SB50 | Uttar Debnagar GPS | N: 22°45′57″ E:89°04′00″ | SST | 21.00 | 2480.06 ± 0.7 | 27.8 ± 0.01 | 61.9 ± 0.05 |

All GPS → Government Primary School.

### 3.2. As content in TWs water

The As content in TWs water of the seven Upazilas at Satkhira district is shown in Tables 1–7. As content in the TWs water of Satkhira proper (Table 1) was ranged from 1.01 to 92.9 μg/L. It is clear from Table 1 that in the TWs of SB01, SB10, SB13, SB14, SB15, SB18, SB19, SB20, SB23, SB30, SB31, SB33, SB34, SB35, SB36, SB37, SB39, SB40, SB41, SB42, and SB48, As content was (< 10 μg/L) at the acceptable level of the world health organization (WHO) guideline value. Also, it is clear from Table 1 that water from the TWs of SB04, SB06, SB07, SB08, SB11, SB12, and SB46, As content was (> 50 μg/L) beyond the Bangladesh drinking standards (BDS) guideline that has been declared unsafe for the children. The rest of the TWs water, As content was (< 50 μg/L) at the acceptable level of BDS guideline but the values were several times higher than the WHO guideline value.

As content in the TWs water of Tala Upazila is shown in Table 2. The lowest amount of As content was in the TW water of SB89 (1.03 μg/L) and the highest amount of As content was in the TW water of SB52 (121.07 μg/L). On average, 32% TWs (16 out of 50) provide As (< 10 μg/L) free water, following the WHO permissible limit. In the TWs of SB54, SB55, SB58, SB59, SB60, SB61, SB63, SB64, SB65, SB66, SB67, SB71, SB74, SB76, SB83, SB84, SB85, SB86, SB91, SB95, and SB99, As content was (> 10 μg/L but < 50 μg/L) at the acceptable level of BDS guideline but the values were several times higher than the WHO guideline value. The remaining 13 TWs water, As content was higher than the BDS level which has been declared for unsafe for the drinking purposes.

As content in the TWs water of Assasuni Upazila is shown in Table 3. It seems that the highest and the lowest amount of As content was in the TWs of SB117 (92.0 μg/L) and TW of SB125 (1.3 μg/L), respectively. In the 20 (twenty) TWs (SB103, SB104, SB105, SB106, SB107, SB108, SB109, SB111, SB113, SB114, SB115, SB121, SB123, SB124, SB125, SB126, SB127, SB128, SB129, and SB130), As content was (< 10 μg/L) at the acceptable level of WHO guideline value. However, in the TWs water of SB101, SB102, SB110, SB112, and SB122, As content was (> 10 μg/L but < 50 μg/L) at the acceptable level of BDS guideline. On

**Table 2**
Sampling points, arsenic, iron and chloride content of Tube wells water at Tala, Bangladesh.

| ID | Location | Sampling points | Type | Depth (m) | Fe (μg/L) | As (μg/L) | Cl (mg/L) |
|---|---|---|---|---|---|---|---|
| SB51 | Mithabari (Uttar) GPS | N:22°46′42″ E:89°07′15″ | DTW | 196.24 | 2549.7 ± 0.5 | 87.4 ± 0.3 | 67.8 ± 0.9 |
| SB52 | Omarpur GPS | N:22°17′00″ E:89°08′30″ | DTW | 200.45 | 690.4 ± 0.4 | 121.07 ± 0.2 | 254.3 ± 0.7 |
| SB53 | Par Madra GPS | N:22°41′37″ E:89°12′23″ | DTW | 185.5 | 39.7 ± 0.17 | 6.01 ± 0.01 | 2543.09 ± 1.5 |
| SB54 | Atulia Paschimpara GPS | N:22°41′55″ E:89°13′59″ | DTW | 177.28 | 30.03 ± 0.07 | 46.7 ± 0.4 | 1763.7 ± 0.6 |
| SB55 | Prantik Nalta GPS | N:22°43′16″ E:89°17′18″ | DTW | 170.66 | 310.1 ± 0.5 | 21.0 ± 0.01 | 108.7 ± 0.7 |
| SB56 | Manikhar GPS | N:22°49′00″ E:89°06′58″ | DTW | 190.68 | 340.04 ± 0.7 | 75.05 ± 0.1 | 380.4 ± 1.03 |
| SB57 | Jhargacha Daulatpur GPS | N:22°47′22″ E:89°07′35″ | DTW | 200.5 | 6819.7 ± 0.5 | 90.8 ± 0.06 | 56.8 ± 0.5 |
| SB58 | Nagarghata Board GPS | N:22°46′54″ E:89°06′30″ | DTW | 185.64 | 1290.02 ± 0.3 | 13.02 ± 0.2 | 48.3 ± 0.15 |
| SB59 | Nagarghata Rahmatia GPS | N:22°45′49″ E:89°06′51″ | DTW | 185.5 | 4140.3 ± 0.07 | 46.8 ± 0.03 | 77.9 ± 0.8 |
| SB60 | Sashadanga GPS | N:22°44′37″ E:89°09′11″ | DTW | 187.8 | 1119.7 ± 0.5 | 39.06 ± 0.4 | 89.3 ± 0.6 |
| SB61 | Avoytala GPS | N:22°47′36″ E:89°10′56″ | DTW | 176.3 | 930.3 ± 0.3 | 11.03 ± 0.07 | 67.9 ± 0.5 |
| SB62 | Ataroi Baruihati GPS | N:22°45′51″ E:89°16′24″ | DTW | 165 | 789.7 ± 0.4 | 86.7 ± 0.3 | 205.3 ± 0.06 |
| SB63 | Barat Monoharpur GPS | N:22°46′15″ E:89°12′01″ | DTW | 182.33 | 110.4 ± 0.05 | 43.4 ± 0.05 | 155.6 ± 1.04 |
| SB64 | Chandkati GPS | N:22°43′30″ E:89°43′30″ | DTW | 170.75 | 3840.05 ± 0.5 | 28.9 ± 0.2 | 218.3 ± 0.7 |
| SB65 | Hazrapara GPS | N:22°44′15″ E 89°11′18″ | DTW | 180.8 | 1339.5 ± 0.7 | 35.3 ± 0.09 | 430.8 ± 0.5 |
| SB66 | Jethua GPS | N:22°42′59″ E:89°16′05″ | DTW | 185.6 | 640.01 ± 0.3 | 29.3 ± 0.1 | 1649.8 ± 1.02 |
| SB67 | Jalalpur Dakkhinpara GPS | N:22°41′56″ E:89°15′29″ | DTW | 210.6 | 629.7 ± 0.5 | 38.06 ± 0.5 | 2112.9 ± 1.3 |
| SB68 | Mohandi GPS | N:22°45′01″ E:89°16′56″ | DTW | 215.8 | 780.1 ± 0.08 | 58.3 ± 0.7 | 1654.07 ± 0.7 |
| SB69 | Satpakia GPS | N:22°40′48″ E:89°14′54″ | DTW | 198 | 2720.5 ± 0.4 | 120.9 ± 0.3 | 2875.9 ± 1.6 |
| SB70 | Enayetpur GPS | N:22°48′24″ E:89°07′51″ | DTW | 205.55 | 2519.6 ± 0.07 | 62.7 ± 0.07 | 230.8 ± 1.5 |
| SB71 | Dhandia GPS | N:22°48′51″ E:89°08′22″ | DTW | 210.67 | 650.3 ± 0.5 | 22.3 ± 0.02 | 1654.4 ± 0.9 |
| SB72 | Krisna Nagar GPS | N:22°49′16″ E:89°08′30″ | DTW | 197.55 | 2949.8 ± 0.09 | 53.8 ± 0.2 | 717.8 ± 1.01 |
| SB73 | Dhukuria-Kaikhali GPS | N:22°41′40″ E:89°11′46″ | DTW | 167.54 | 630.06 ± 0.3 | 5.05 ± 0.1 | 2543.03 ± 0.8 |
| SB74 | Dudli GPS | N:22°43′09″ E:89°10′36″ | DTW | 187.45 | 3540.4 ± 0.07 | 36.9 ± 0.2 | 1241.7 ± 0.7 |
| SB75 | Kaikhali GPS | N:22°41′41″ E:89°11′25″ | DTW | 177.78 | 3069.7 ± 0.7 | 6.3 ± 0.07 | 2217.8 ± 0.6 |
| SB76 | Khalishkhali Jadunath GPS | N:22°42′53″ E:89°11′10″ | DTW | 173 | 1260.03 ± 0.4 | 23.7 ± 0.01 | 1109.8 ± 1.03 |
| SB77 | Khalishkhali GPS | N:22°43′27″ E:89°11′06″ | DTW | 229.5 | 1080.4 ± 0.6 | 8.05 ± 0.03 | 2353.8 ± 1.2 |
| SB78 | Mirzapur Model GPS | N:22°46′52″ E:89°12′13″ | DTW | 210.5 | 1760.07 ± 0.9 | 5.01 ± 0.01 | 764.7 ± 0.9 |
| SB79 | Kumira GPS | N:22°46′07″ E:89°10′24″ | DTW | 198.6 | 3739.7 ± 0.7 | 5.04 ± 0.1 | 353.8 ± 0.6 |
| SB80 | B. B GPS | N:22°43′01″ E:89°13′00″ | DTW | 185.77 | 320.4 ± 0.08 | 3.03 ± 0.02 | 2654.06 ± 1.7 |
| SB81 | Nagarghata Gabtala GPS | N:22°46′48″ E:89°06′05″ | DTW | 177.5 | 370.3 ± 0.5 | 3.01 ± 0.07 | 613.9 ± 0.8 |
| SB82 | Sammandanga GPS | N:22°48′11″ E:89°05′25″ | DTW | 180.5 | 429.8 ± 0.06 | 2.0 ± 0.05 | 967.9 ± 1.3 |
| SB83 | Nagarghata Kalibari GPS | N:22°46′27″ E:89°06′57″ | DTW | 153 | 250.09 ± 0.3 | 37.9 ± 0.4 | 1186.9 ± 1.4 |
| SB84 | Sarulia GPS | N:22°47′57″ E:89°08′27″ | DTW | 157.6 | 2439.8 ± 1.0 | 32.09 ± 0.03 | 852.7 ± 1.07 |
| SB85 | Bharsha GPS | N:22°44′59″ E:89°10′40″ | DTW | 175 | 2610.4 ± 0.5 | 19.05 ± 0.04 | 1085.9 ± 0.8 |
| SB86 | Bara Bila GPS | N:22°47′05″ E:89°08′56″ | DTW | 185.82 | 2259.7 ± 0.7 | 41.6 ± 0.07 | 423.01 ± 1.0 |
| SB87 | Madra GPS | N:22°41′44″ E:89°12′57″ | DTW | 190.52 | 1640.3 ± 0.4 | 1.04 ± 0.03 | 2987.9 ± 1.5 |
| SB88 | Baichan GPS | N:22°41′25″ E:89°13′25″ | DTW | 176 | 1840.2 ± 0.8 | 7.9 ± 0.02 | 2097.9 ± 0.9 |
| SB89 | Amradanga GPS | N:22°41′42″ E:89°14′44″ | DTW | 175 | 490.09 ± 0.03 | 1.03 ± 0.01 | 2255.9 ± 1.7 |
| SB90 | Salika Gussagram GPS | N:22°39′37″ E:89°15′04″ | DTW | 170.45 | 2209.7 ± 0.7 | 1.09 ± 0.05 | 3217.9 ± 1.6 |
| SB91 | Tegharia GPS | N:22°40′32″ E:89°15′21″ | DTW | 165.88 | 2870.4 ± 0.9 | 16.8 ± 0.1 | 1658.07 ± 0.8 |
| SB92 | Dumuria GPS | N:22°39′38″ E:89°16′15″ | DTW | 160.24 | 650.01 ± 0.1 | 3.07 ± 0.2 | 2234.8 ± 1.01 |
| SB93 | Dumuria Purbopara GPS | N:22°39′18″ E:89°16′27″ | DTW | 146.77 | 3780.4 ± 0.3 | 2.03 ± 0.1 | 3174.9 ± 0.8 |
| SB94 | Uttor Shahajatpur GPS | N:22°39′02″ E:89°16′45″ | DTW | 165.32 | 2139.9 ± 1.01 | 5.07 ± 0.03 | 1878.6 ± 1.0 |
| SB95 | Shankdha GPS | N:22°45′53″ E:89°08′36″ | DTW | 177.8 | 910.06 ± 0.4 | 24.9 ± 0.05 | 1568.06 ± 0.6 |
| SB96 | Sujansaha GPS | N:22°44′47″ E:89°13′38″ | DTW | 194.52 | 1209.01 ± 0.8 | 78.7 ± 0.4 | 623.01 ± 0.3 |
| SB97 | Pranpur GPS | N:22°43′59″ E:89°13′40″ | DTW | 195.32 | 1050.3 ± 1.02 | 69.08 ± 0.5 | 285.9 ± 0.7 |
| SB98 | Bhabanipr GPS | N:22°46′12″ E:89°13′31″ | DTW | 168.66 | 650.07 ± 0.3 | 60.01 ± 0.1 | 1067.9 ± 1.03 |
| SB99 | Tentulia GPS | N:22°47′23″ E:89°15′03″ | DTW | 185.85 | 190.3 ± 0.07 | 22.07 ± 0.1 | 38.7 ± 0.4 |
| SB100 | Aladipur GPS | N:22°48′12″ E:89°15′33″ | DTW | 200 | 1429.3 ± 0.3 | 88.7 ± 0.03 | 87.05 ± 0.5 |

the other hand, in the TWs water of SB116, SB117, SB118, SB119, and SB120, As content was (> 50 μg/L) beyond the BDS limit and several times higher than the WHO guideline value, hence, those TWs water have been declared unsafe for the drinking purposes.

Table 4 shows the As content in the TWs water of Kalaroa Upazila. The lowest amount of As content was detected with 1.0 μg/L (SB152, Dakkhin Bhadiali GPS) and the highest amount of As content was detected 167.9 μg/L (SB158, Narayanpur GPS). On average, 46.7% TWs (14 out of 30) provide As (< 10 μg/L) free water, following for both the BDS and WHO permissible limit. In the TWs water of SB131, SB132, SB134, SB139, SB141, SB143, SB145, SB147, SB150, SB151, and SB156, As content were (> 10 μg/L but < 50 μg/L) higher than the WHO guideline but within the BDS permissible level. As content in the TWs water of SB135, SB155, SB158, SB159, and SB160 was beyond the BDS level, which was several times higher than the WHO guideline value, therefore, it has been stated unsafe for the drinking purposes.

As content in the TWs water of Kaliganj Upazila is shown in Table 5. The highest and the lowest amount of As content was found in the TWs water of SB178 (123.7 μg/L) and SB162 (1.0 μg/L), respectively. Only, 26.7% TWs water (8 out of 30), As content was (< 10 μg/L) at the acceptable level of the WHO guideline value. On average, 43.3% TWs (13 out of 30) water, As content was (> 10 μg/L but < 50 μg/L) higher than the WHO guideline but within the BDS limit. The 30% TWs (9 out of 30) water, As content was beyond the BDS level, which has been considered unsafe for the drinking purposes.

Accordingly, As content in the TWs water of Shaymnagar Upazila is shown in Table 6. It appears that the highest and the lowest amount of As content was in the TWs water of SB195 (163.9 μg/L) and of SB202 (1.0 μg/L), respectively. The 83.3% TWs (25 out of 30) water, As content was (< 10 μg/L) at the acceptable level of WHO guideline value. Only, in the TWs water of SB205, SB217, and SB218, As content was (> 10 μg/L but < 50 μg/L) higher than the WHO guideline but within the BDS limit. Among the 30 TWs water, only in the 2 (two) TWs water (SB195 and SB201), As content was beyond the BDS permissible level.

As content in the TWs water of the Debhata Upazila is shown in Table 7. In the TW water of SB240, As content was the highest (36.9 μg/L) and in the TW water of SB232 As content was the lowest (1.0 μg/L). In the 90% TWs (18 out of 20) water, As content (< 10 μg/L) was at the

**Table 3**
Sampling points, arsenic, iron and chloride content of Tube wells water at Assasuni, Bangladesh.

| ID | Location | Sampling points | Type | Depth (m) | Fe (μg/L) | As (μg/L) | Cl (mg/L) |
|---|---|---|---|---|---|---|---|
| SB101 | Badar Tala GPS | N:22°35′16″ E:89°03′47″ | DTW | 181.4 | 229.08 ± 0.9 | 15.04 ± 0.4 | 653.7 ± 1.4 |
| SB102 | Natana GPS | N:22°29′52″ E:89°09′34″ | DTW | 149.39 | 2260.4 ± 1.1 | 15.6 ± 0.07 | 445.04 ± 0.8 |
| SB103 | Haskhali GPS | N:22°30′30″ E:89°10′31″ | DTW | 137.2 | 119.8 ± 1.7 | 8.04 ± 0.3 | 356.3 ± 1.01 |
| SB104 | Burakharati GPS | N:22°26′45″ E:89°09′42″ | DTW | 158.54 | 3230.4 ± 1.9 | 7.01 ± 0.2 | 367.9 ± 0.7 |
| SB105 | Modhom Eksara GPS | N:22°24′55″ E:89°14′17″ | DTW | 164.63 | 229.7 ± 0.9 | 9.03 ± 0.03 | 425.6 ± 1.2 |
| SB106 | Nangla GPS | N:22°24′07″ E:89°14′40″ | DTW | 155.49 | 250.3 ± 1.04 | 5.05 ± 0.2 | 348.0 ± 0.5 |
| SB107 | Diglar Ait GPS | N:22°21′25″ E:89°14′57″ | DTW | 134.15 | 189.8 ± 0.6 | 3.02 ± 0.1 | 1794.6 ± 1.2 |
| SB108 | Laskari Khajra GPS | N:22°24′06″ E:89°12′48″ | DTW | 149.39 | 210.03 ± 0.7 | 8.04 ± 0.2 | 231.7 ± 0.4 |
| SB109 | Pratap Nagar GPS | N:22°22′58″ E:89°12′35″ | DTW | 161.59 | 419.6 ± 1.0 | 8.01 ± 0.1 | 114.8 ± 1.03 |
| SB110 | Kuri Kahunia Girls GPS | N:22°22′55″ E:89°13′38″ | DTW | 140.24 | 1420.02 ± 1.03 | 25.9 ± 0.4 | 75.4 ± 0.7 |
| SB111 | Subhadra Kati GPS | N:22°22′03″ E:89°15′46″ | DTW | 149.39 | 409.7 ± 0.5 | 2.03 ± 0.02 | 631.7 ± 0.6 |
| SB112 | Kakrabunia GPS | N:22°25′28″ E:89°08′55″ | DTW | 160.06 | 149.5 ± 0.04 | 10.9 ± 0.4 | 85.01 ± 0.23 |
| SB113 | Puijala GPS | N:22°28′29″ E:89°11′21″ | DTW | 130.5 | 410.4 ± 0.12 | 8.04 ± 0.01 | 864.2 ± 1.4 |
| SB114 | Kalyanpur GPS | N:22°23′21″ E:89°12′17″ | DTW | 137.5 | 389.9 ± 0.6 | 3.01 ± 0.1 | 234.6 ± 0.14 |
| SB115 | Nakna GPS | N:22°23′39″ E:89°13′38″ | DTW | 122.5 | 710.04 ± 0.07 | 8.05 ± 0.5 | 211.7 ± 0.7 |
| SB116 | Naikati GPS | N:22°33′38″ E:89°07′41″ | STW | 21.34 | 3519.8 ± 1.01 | 71.06 ± 0.1 | 342.08 ± 0.5 |
| SB117 | Madham Beula GPS | N:22°35′19″ E:89°08′30″ | STW | 23.48 | 229.7 ± 0.6 | 92.0 ± 0.3 | 233.6 ± 0.13 |
| SB118 | Maheswarkati GPS | N:22°35′04″ E:89°10′13″ | STW | 25.91 | 280.3 ± 0.4 | 72.01 ± 0.01 | 342.05 ± 0.5 |
| SB119 | Beula GPS | N:22°34′45″ E:89°08′27″ | STW | 23.48 | 219.6 ± 0.13 | 76.7 ± 0.04 | 374.7 ± 0.02 |
| SB120 | D.K.S Dhannohati GPS | N:22°32′13″ E:89°08′35″ | STW | 23.48 | 2979.6 ± 1.6 | 51.9 ± 0.5 | 585.1 ± 0.3 |
| SB121 | Mohishkur GPS | N:22°27′07″ E:89°09′21″ | DTW | 128.04 | 140.4 ± 0.7 | 5.7 ± 0.1 | 811.7 ± 0.7 |
| SB122 | Bagali GPS | N:22°27′04″ E:89°14′42″ | DTW | 132 | 170.01 ± 0.4 | 11.7 ± 0.03 | 2015.01 ± 1.2 |
| SB123 | Baro Durgapur GPS | N:22°32′30″ E:89°09′48″ | STW | 23.5 | 609.8 ± 1.0 | 3.8 ± 0.04 | 993.8 ± 0.6 |
| SB124 | Dakkhin Puijala GPS | N:22°27′07″ E:89°09′21″ | DTW | 142 | 7620.04 ± 0.7 | 2.13 ± 0.1 | 1279.01 ± 0.2 |
| SB125 | Eksora GPS | N:22°25′11″ E:89°13′47″ | DTW | 157 | 320.1 ± 0.6 | 1.3 ± 0.06 | 212.13 ± 0.6 |
| SB126 | Uttar Baradal GPS | N:22°32′11″ E:89°14′29″ | STW | 25.8 | 2779.7 ± 0.03 | 2 ± 0.2 | 528.4 ± 0.3 |
| SB127 | Mojgurkhali GPS | N:22°35′41″ E:89°03′39″ | DTW | 152.5 | 110.13 ± 0.04 | 1.0 ± 0.02 | 132.3 ± 0.5 |
| SB128 | Dakkhin Puijala GPS | N:22°26′56″ E:89°11′28″ | DTW | 149.3 | 1610.4 ± 0.6 | 4.07 ± 0.05 | 609.9 ± 0.09 |
| SB129 | Kakbasia GPS | N:22°27′13″ E:89°12′44″ | DTW | 23.48 | 8319.8 ± 0.3 | 3.1 ± 0.1 | 4736.2 ± 1.01 |
| SB130 | Anulia GPS | N:22°26′15″ E:89°13′02″ | DTW | 128 | 1900.02 ± 0.09 | 5.07 ± 0.01 | 1033.07 ± 0.8 |

**Table 4**
Sampling points, arsenic, iron and chloride content of Tube wells water at Kalaroa, Bangladesh.

| ID | Location | Sampling points | Type | Depth (m) | Fe (μg/L) | As (μg/L) | Cl (mg/L) |
|---|---|---|---|---|---|---|---|
| SB131 | Nathpur GPS | N:22°53′37″ E:88°58′18″ | TDTW | 118.9 | 1780.1 ± 0.5 | 48.0 ± 0.1 | 89.02 ± 0.3 |
| SB132 | Jalalabad GPS | N:22°51′25″ E:89°03′57″ | TDTW | 128.02 | 1819.7 ± 0.07 | 40.8 ± 0.2 | 126.17 ± 0.8 |
| SB133 | Talundia GPS | N:22°54′28″ E:89°06′35″ | TDTW | 166.12 | 740.0 ± 0.03 | 1.01 ± 0.03 | 1033.7 ± 1.03 |
| SB134 | South Dhandia GPS | N:22°49′34″ E:89°07′48″ | TDTW | 175.26 | 110.1 ± 0.4 | 19.4 ± 0.02 | 946.9 ± 0.5 |
| SB135 | Kakdanga Uttar GPS | N:22°49′50″ E:88°58′36″ | TDTW | 121.92 | 2729.7 ± 0.01 | 145.01 ± 0.5 | 61.0 ± 0.7 |
| SB136 | Madhya Kakdanga GPS | N:22°49′41″ E:88°58′39″ | TDTW | 196.6 | 2320.05 ± 0.6 | 1.01 ± 0.1 | 714.04 ± 1.01 |
| SB137 | Gopinathpur GPS | N:22°49′37″ E:89°02′23″ | TDTW | 246.89 | 90.1 ± 0.5 | 1 .03 ± 0.2 | 4324.4 ± 1.5 |
| SB138 | Lanjaljhara GPS | N:22°51′00″ E:89°01′01″ | TDTW | 199.64 | 170.02 ± 0.19 | 1.07 ± 0.3 | 873.8 ± 0.7 |
| SB139 | Raitha Sobujbag GPS | N:22°53′27″ E:89°03′23″ | TDTW | 121.92 | 1709.6 ± 0.4 | 14.03 ± 0.07 | 987.8 ± 1.4 |
| SB140 | Helatala GPS | N:22°53′14″ E:89°02′22″ | TDTW | 121.92 | 2079.6 ± 0.07 | 9.3 ± 0.17 | 341.8 ± 0.8 |
| SB141 | Shankarpur GPS | N:22°51′07″ E:89°04′46″ | TDTW | 158.5 | 110.0 ± 0.5 | 38.7 ± 0.5 | 981.7 ± 0.5 |
| SB142 | Basantapur GPS | N:22°52′02″ E:89°06′07″ | TDTW | 175.26 | 119.6 ± 0.06 | 3.02 ± 0.02 | 988.03 ± 1.2 |
| SB143 | Nilkanthapur GPS | N:22°50′13″ E:89°06′52″ | TDTW | 155.5 | 310.03 ± 0.3 | 36.3 ± 0.3 | 936.9 ± 1.0 |
| SB144 | Panchpota GPS | N 22°51′40″ E:89°00′16″ | TDTW | 216.41 | 580.0 ± 0.13 | 1.03 ± 0.06 | 985.7 ± 0.9 |
| SB145 | Bolianpur GPS | N:22°53′35″ E:88°59′47″ | TDTW | 118.9 | 3750.3 ± 0.5 | 46.8 ± 0.5 | 79.0 ± 1.1 |
| SB146 | Darbasha GPS | N:22°54′36″ E:89°00′10″ | TDTW | 170.7 | 149.6 ± 1.3 | 2.01 ± 0.1 | 979.05 ± 0.7 |
| SB147 | Kalaroa GPS | N:22°51′27″ E:89°02′27″ | TDTW | 128.02 | 1510.01 ± 0.5 | 43.07 ± 0.3 | 99.03 ± 1.6 |
| SB148 | Kumarnal GPS | N:22°50′23″ E:89°03′28″ | TDTW | 123.4 | 150.3 ± 0.4 | 6.0 ± 0.04 | 989.07 ± 1.15 |
| SB149 | Shahapur GPS | N:22°50′59″ E:89°00′29″ | TDTW | 190.5 | 390.1 ± 0.03 | 1.01 ± 0.01 | 478.9 ± 1.2 |
| SB150 | Nakila GPS | N:22°54′22″ E:89°00′32″ | TDTW | 118.27 | 2190.2 ± 0.4 | 47.3 ± 0.02 | 99.03 ± 0.7 |
| SB151 | Tulshidanga GPS | N:22°52′06″ E:89°02′30″ | TDTW | 128.02 | 3420.0 ± 0.03 | 40.8 ± 0.07 | 103.1 ± 0.8 |
| SB152 | Dakkhin Bhadiali GPS | N:22°50′26″ E:88°58′15″ | TDTW | 184.4 | 140.06 ± 0.4 | 1.0 ± 0.01 | 227.8 ± 0.5 |
| SB153 | Razpur GPS | N:22°52′08″ E:88°58′06″ | TDTW | 210.32 | 740.01 ± 0.05 | 5.01 ± 0.3 | 786.0 ± 1.3 |
| SB154 | Uttar Bhadiali GPS | N:22°51′18″ E:88°57′52″ | TDTW | 195.1 | 2489.9 ± 0.7 | 4.05 ± 0.1 | 467.8 ± 0.5 |
| SB155 | Khordo Pakuria GPS | N:22°55′22″ E:89°05′54″ | TDTW | 180.26 | 6230.04 ± 0.2 | 139.0 ± 0.3 | 225.06 ± 0.7 |
| SB156 | Diara GPS | N:22°55′04″ E:89°06′57″ | TDTW | 190.32 | 740.1 ± 0.7 | 41.7 ± 0.05 | 240.01 ± 1.1 |
| SB157 | Keragachi Dakkhinpara GPS | N:22°48′52″ E:88°57′48″ | TDTW | 170.84 | 80.05 ± 0.3 | 6.01 ± 0.09 | 1211.04 ± 1.0 |
| SB158 | Narayanpur GPS | N:22°51′45″ E:89°04′45″ | TDTW | 155.5 | 130.09 ± 0.04 | 167.9 ± 0.6 | 60.8 ± 0.7 |
| SB159 | Akra GPS | N:22°49′15″ E:89°04′43″ | TDTW | 170.7 | 530.0 ± 1.3 | 142.9 ± 1.0 | 54.7 ± 0.8 |
| SB160 | Jhikra GPS | N:22°50′51″ E:89°02′28″ | TDTW | | 1320.02 ± 0.7 | 79.03 ± 0.5 | 51.07 ± 1.6 |

acceptable level of WHO guideline value. Only, in the 10% TWs (2 out of 20) water, As content ( > 10 μg/L but < 50 μg/L) was higher than the WHO guideline but within the BDS limit.

According to the oxidation theory, As is desorbed from the shallow aquifer due to the oxidation of sulphide minerals (arsenopyrite). Because of over-exploitation of groundwater for irrigation, atmospheric oxygen enters into the aquifers where it reacts with the arsenopyrite (Eq. v), which influences the release of As into the groundwater (Neil et al., 2012). The typical symptoms of As exposure are skin lesions, developmental effects, cardiovascular disease, melanosis, keratosis,

**Table 5**
Sampling points, arsenic, iron and chloride content of Tube wells water at Kaliganj, Bangladesh.

| ID | Location | Sampling points | Type | Depth (m) | Fe (μg/L) | As (μg/L) | Cl (mg/L) |
|---|---|---|---|---|---|---|---|
| SB161 | Shibpur GPS | N:22°21′41″ E:88°59′32″ | DTW | 188 | 129.8 ± 0.5 | 19.01 ± 0.07 | 243.1 ± 1.07 |
| SB162 | Bashjharia GPS | N:22°22′39″ E:89°00′02″ | DTW | 200 | 110.01 ± 0.08 | **1.0 ± 0.1** | 240.9 ± 0.7 |
| SB163 | Thalna GPS | N:22°29′43″ E:89°09′17″ | DTW | 157 | 90.4 ± 0.3 | 2.05 ± 0.02 | 175.6 ± 0.8 |
| SB164 | Rajnagar GPS | N:22°22′16″ E:89°07′20″ | STW | 40 | 2149.7 ± 0.6 | 42.7 ± 0.3 | 1876.0 ± 0.17 |
| SB165 | Bandakati GPS | N:22°25′50″ E:89°08′04″ | SST | 13 | 80.4 ± 0.08 | 14.6 ± 0.4 | 457.8 ± 0.9 |
| SB166 | Chunakhali GPS | N:22°20′59″ E:89°02′20″ | STW | 41 | 1319.7 ± 0.13 | 31.5 ± 0.05 | 902.8 ± 1.0 |
| SB167 | Fatehpur GPS | N:22°26′51″ E:89°07′35″ | STW | 16 | 3230.03 ± 0.7 | 63.03 ± 0.06 | 968.03 ± 1.1 |
| SB168 | Kalijoga GPS | N:22°25′52″ E:89°03′24″ | STW | 41 | 69.6 ± 0.17 | 35.8 ± 0.1 | 751.7 ± 0.7 |
| SB169 | Uttar Kaliganj GPS | N:22°27′31″ E:89°01′54″ | STW | 45 | 4220.3 ± 0.7 | 47.07 ± 0.3 | 1324.8 ± 0.8 |
| SB170 | Roghurampur GPS | N:22°23′54″ E:89°01′43″ | SST | 15 | 619.7 ± 1.03 | 23.07 ± 0.09 | 497.7 ± 1.07 |
| SB171 | Masjidbati GPS | N:22°23′32″ E:89°02′04″ | STW | 46 | 1280.0 ± 0.8 | 48.05 ± 0.03 | 218.03 ± 0.9 |
| SB172 | Pania GPS | N:22°25′13″ E:89°03′18″ | STW | 55 | 2410.09 ± 0.5 | 64.9 ± 0.4 | 127.7 ± 0.5 |
| SB173 | Goneshpur GPS | N:22°23′36″ E:89°01′15″ | STW | 49 | 330.07 ± 0.4 | 35.03 ± 0.5 | 153.8 ± 0.9 |
| SB174 | Muragacha GPS | N:22°21′42″ E:89°00′32″ | DTW | 175 | 180.3 ± 0.06 | 3.01 ± 0.07 | 769.01 ± 0.9 |
| SB175 | M.M. Pur GPS | N:22°25′22″ E:89°06′59″ | DTW | 187 | 189.6 ± 0.7 | 42.7 ± 0.1 | 735.03 ± 1.1 |
| SB176 | Ghona Magri GPS | N:22°29′41″ E:89°01′22″ | DTW | 176 | 2240.0 ± 0.5 | 18.9 ± 0.2 | 531.9 ± 0.7 |
| SB177 | Namazgar GPS | N:22°24′48″ E:89°04′47″ | DTW | 170 | 179.8 ± 0.7 | 30.8 ± 0.6 | 71.8 ± 0.5 |
| SB178 | Bhagoban Jasomontapur GPS | N:22°27′17″ E:89°07′14″ | STW | 56 | 7169.7 ± 1.05 | 123.7 ± 0.07 | 1324.7 ± 0.08 |
| SB179 | Gobindapur GPS | N:22°25′02″ E:89°01′03″ | STW | 46 | 1150.03 ± 0.09 | 7.01 ± 0.3 | 98.04 ± 0.6 |
| SB180 | Uksha GPS | N:22°25′33″ E:89°00′25″ | TDTW | 232 | 379.7 ± 0.6 | 1.01 ± 0.04 | 74.1 ± 1.02 |
| SB181 | Nalta GPS | N:22°30′51″ E:89°00′56″ | STW | 55 | 6880.08 ± 1.05 | 61.8 ± 0.02 | 1314.3 ± 0.7 |
| SB182 | Laki Kamorpur GPS | N:22°24′50″ E:89°07′12″ | STW | 32 | 2229.7 ± 0.08 | 75.6 ± 0.01 | 2567.6 ± 1.3 |
| SB183 | Gopalpur GPS | N:22°29′59″ E:89°03′51″ | STW | 42 | 4479.8 ± 0.8 | 97.03 ± 0.6 | 1270.01 ± 0.9 |
| SB184 | Dadpur GPS | N:22°29′15″ E:89°00′10″ | STW | 33 | 1220.01 ± 1.1 | 76.8 ± 0.05 | 93.02 ± 0.13 |
| SB185 | Benadanga GPS | N:22°22′57″ E:89°07′07″ | STW | 35 | 759.6 ± 0.06 | 3.03 ± 0.2 | 768.9 ± 0.8 |
| SB186 | Paschim Kakapur | N:22°24′01″ E:89°08′20″ | STW | 45 | 5760.07 ± 0.7 | 114.6 ± 0.13 | 1398.4 ± 1.02 |
| SB187 | Kaliganj Sadar GPS | N:22°27′24″ E:89°01′57″ | STW | 45 | 170.3 ± 0.4 | 5.07 ± 0.03 | 95.06 ± 0.06 |
| SB188 | Chingra GPS | N:22°26′26″ E:89°00′11″ | STW | 58 | 109.7 ± 0.07 | 4.0 ± 0.2 | 1985.7 ± 1.5 |
| SB189 | Dattanagar GPS | N:22°20′59″ E:89°03′08″ | STW | 43 | 440.0 ± 0.5 | 37.9 ± 0.04 | 912.3 ± 0.35 |
| SB190 | Kharhat GPS | N:22°28′43″ E:89°00′11″ | SST | 14 | 2560.4 ± 0.2 | 85.7 ± 0.03 | 1358.07 ± 0.4 |

**Table 6**
Sampling points, arsenic, iron and chloride content of Tube wells water at Shyamnagar, Bangladesh.

| ID | Location | Sampling points | Type | Depth (m) | Fe (μg/L) | As (μg/L) | Cl (mg/L) |
|---|---|---|---|---|---|---|---|
| SB191 | Gona GPS | N:22°17′32″ E:89°01′51″ | DTW | 152.44 | 1319.7 ± 1.4 | 1.01 ± 0.1 | 1235.01 ± 1.0 |
| SB192 | Katamari GPS | N:22°15′46″ E:89°01′30″ | DTW | 155.49 | 639.9 ± 1.09 | 1.1 ± 0.03 | 542.9 ± 0.9 |
| SB193 | Bonnatala United GPS | N:22°22′32″ E:89°13′11″ | DTW | 170 | 120.07 ± 0.7 | 1.07 ± 0.2 | 338.7 ± 1.05 |
| SB194 | Gopalpur GPS | N:22°20′26″ E:89°05′29″ | STW | 57.93 | 3480.01 ± 1.1 | 1.01 ± 0.1 | 52.7 ± 0.8 |
| SB195 | Harinagar (Moktob) GPS | N:22°14′22″ E:89°07′56″ | STW | 57 | 2189.9 ± 0.8 | 163.9 ± 0.5 | 3465.06 ± 1.07 |
| SB196 | Dakkhin Sreefalkati GPS | N:22°16′43″ E:89°07′32″ | STW | 60 | 7660.1 ± 1.05 | 5.03 ± 0.4 | 3677.9 ± 1.6 |
| SB197 | Bhamia Porakatla GPS | N:22°16′40″ E:89°14′16″ | STW | 68.6 | 6500.01 ± 1.3 | 3.02 ± 0.05 | 2644.8 ± 0.7 |
| SB198 | Choto Kupot GPS | N:22°19′51″ E:89°10′57″ | STW | 64 | 2119.7 ± 1.04 | 1.3 ± 0.01 | 1746.4 ± 1.02 |
| SB199 | Dakkhin Baro Kupot GPS | N:22°18′47″ E:89°12′49″ | STW | 61 | 350.04 ± 0.6 | 1.07 ± 0.3 | 2349.03 ± 1.5 |
| SB200 | Hatchhala GPS | N:22°22′15″ E:89°06′20″ | STW | 59.45 | 1759.7 ± 0.7 | 1.03 ± 0.04 | 2586.8 ± 0.9 |
| SB201 | Paschim Chingrakhali GPS | N:23°08′10″ E:89°16′27″ | STW | 60 | 2319.8 ± 0.8 | 55.8 ± 0.5 | 3858.4 ± 0.5 |
| SB202 | Habibpur (Horipur) GPS | N:22°18′54″ E:89°02′51″ | STW | 56.4 | 2620.03 ± 0.4 | 1.0 ± 0.1 | 3075.7 ± 1.05 |
| SB203 | Dhankhali GPS | N:22°15′56″ E:89°10′29″ | STW | 55 | 2129.7 ± 0.7 | 1.3 ± 0.02 | 8119.04 ± 1.3 |
| SB204 | Dakkhin Dhumghat GPS | N:22°14′14″ E:89°07′29″ | STW | 57 | 109.7 ± 0.8 | 5.0 ± 0.04 | 3467.8 ± 1.01 |
| SB205 | Dakkhin Bongshipur GPS | N:22°17′55″ E:89°05′54″ | STW | 56.4 | 2430.07 ± 0.6 | 31.8 ± 0.06 | 4432.3 ± 0.8 |
| SB206 | Central Abad Chondipur GPS | N:22°16′54″ E:89°10′27″ | STW | 59 | 149.7 ± 0.05 | 2.9 ± 0.2 | 2653.6 ± 1.1 |
| SB207 | Maddhya Atulia GPS | N:22°20′10″ E:89°10′42″ | STW | 64 | 50.06 ± 0.3 | 1.05 ± 0.04 | 2236.05 ± 0.6 |
| SB208 | Buri Goalini Datinakhali GPS | N:22°15′33″ E:89°13′42″ | STW | 59.45 | 5719.6 ± 1.04 | 2.07 ± 0.11 | 1988.7 ± 0.02 |
| SB209 | Baintala GPS | N:22°19′46″ E:89°14′26″ | STW | 56.4 | 1010.07 ± 0.5 | 7.02 ± 0.03 | 579.07 ± 0.4 |
| SB210 | Soalia GPS | N:22°20′07″ E:89°04′34″ | SST | 20.73 | 180.04 ± 0.7 | 8.6 ± 0.4 | 2895.3 ± 1.03 |
| SB211 | Durmujkhali Bhobani Sundari GPS | N:22°18′28″ E:89°01′30″ | SST | 21.34 | 320.0 ± 0.5 | 1.01 ± 0.01 | 1249.3 ± 0.9 |
| SB212 | Paschim Koikhali GPS | N:22°13′42″ E:89°00′09″ | SST | 19.82 | 759.60 ± 1.03 | 1.03 ± 0.4 | 9987.01 ± 0.6 |
| SB213 | Ishwaripur GPS | N:22°18′07″ E:89°07′00″ | SST | 20.73 | 539.7 ± 0.6 | 2.0 ± 0.03 | 4763.9 ± 1.07 |
| SB214 | Ramchandrapur GPS | N:22°19′30″ E:89°02′20″ | SST | 20.73 | 429.7 ± 0.7 | 1.04 ± 0.07 | 2247.3 ± 1.02 |
| SB215 | Haibatpur GPS | N:22°20′14″ E:89°06′26″ | SST | 12.8 | 39.8 ± 0.06 | 1.02 ± 0.01 | 3233.9 ± 0.7 |
| SB216 | 169 no. Purba Gumantoli GPS | N:22°18′17″ E:89°08′55″ | STW | 56 | 1030.01 ± 0.8 | 3.1 ± 0.1 | 1763.04 ± 0.07 |
| SB217 | Sreefalkati Paschimpara GPS | N:22°17′33″ E:89°06′09″ | STW | 67 | 119.2 ± 0.6 | 14.3 ± 0.03 | 3863.8 ± 0.2 |
| SB218 | Purba Durgabati GPS | N:22°16′24″ E:89°14′41″ | DTW | 61 | 2340.04 ± 0.7 | 11.8 ± 0.2 | 1986.7 ± 0.09 |
| SB219 | Jabakhali GPS | N:22°18′15″ E:89°10′02″ | STW | 55 | 659.7 ± 1.03 | 1.07 ± 0.01 | 1876.0 ± 1.0 |
| SB220 | Dakkhin Koikhali GPS | N:22°12′50″ E:89°03′32″ | DTW | 113.41 | 1470.01 ± 0.6 | 1.0 ± 0.04 | 8586.07 ± 1.1 |

ulcer, gangrene, peripheral vascular disorder, lung disease, kidney failure, liver failure, neurotoxicity and arsenicosis (FAO et al., 2010).

$$4FeAsS + 6H_2O + 11O_2 \rightarrow 4Fe^{2+} + 4H_3AsO_3 + 4SO_4^{2-} \quad (v)$$

### 3.3. Fe content in TWs water

Fe content in the TWs water of seven Upazilas at Satkhira district is shown in Tables 1–7. Fe content in the TWs water at Satkhira proper (Table 1) was ranged from 10.01 to 13479.6 μg/L. The highest and the

**Table 7**
Sampling points, arsenic, iron and chloride content of Tube wells water at Debhata, Bangladesh.

| ID | Location | Sampling points | Type | Depth (m) | Fe (μg/L) | As (μg/L) | Cl (mg/L) |
|---|---|---|---|---|---|---|---|
| SB221 | Baliadanga GPS | N:22°38′25″ E:89°00′05″ | DTW | 122 | 279.8 ± 0.3 | 7.9 ± 0.3 | 105.3 ± 1.01 |
| SB222 | Enampur GPS | N:22°33′51″ E:88°58′07″ | STW | 65 | 120.01 ± 0.5 | 8.01 ± 0.07 | 46.3 ± 0.8 |
| SB223 | Debishahor GPS | N:22°32′54″ E:89°01′13″ | STW | 66 | 109.7 ± 0.06 | 1.1 ± 0.3 | 94.7 ± 0.06 |
| SB224 | Hadipur GPS | N:22°32′11″ E:89°00′47″ | STW | 70 | 2650.01 ± 0.5 | 1.04 ± 0.02 | 218.0 ± 0.5 |
| SB225 | Shusilgati GPS | N:22°33′39″ E:88°57′19″ | STW | 68 | 259.7 ± 0.07 | 1.2 ± 0.3 | 545.8 ± 1.03 |
| SB226 | Uttar Askarpur GPS | N:22°31′51″ E:89°01′15″ | STW | 25.5 | 250.04 ± 0.1 | 1.4 ± 0.07 | 397.8 ± 0.8 |
| SB227 | Ghalghalia GPS | N:22°35′32″ E:88°57′21″ | DTW | 204.27 | 260.07 ± 0.7 | 2.01 ± 0.04 | 631.6 ± 1.08 |
| SB228 | Bohera GPS | N:22°38′59″ E:88°59′35″ | DTW | 128.04 | 1319.7 ± 0.4 | 1.06 ± 0.1 | 118.05 ± 0.7 |
| SB229 | Khaskhamar GPS | N:22°39′31″ E:88°59′49″ | DTW | 128.04 | 290.6 ± 0.03 | 5.9 ± 0.03 | 214.9 ± 0.2 |
| SB230 | Kulia Siddiswari GPS | N:22°38′22″ E:88°59′40″ | DTW | 128.04 | 649.7 ± 0.01 | 7.7 ± 0.01 | 77.8 ± 0.1 |
| SB231 | Simulia GPS | N:22°33′25″ E:89°00′24″ | DTW | 224.08 | 780.04 ± 0.5 | 3.05 ± 0.2 | 966.7 ± 0.4 |
| SB232 | Sungbaria GPS | N:22°33′30″ E:89°00′55″ | DTW | 228.66 | 250.1 ± 0.06 | 1.0 ± 0.01 | 157.8 ± 0.7 |
| SB233 | Narikeli GPS | N:22°34′57″ E:88°59′25″ | DTW | 134.15 | 739.6 ± 0.2 | 3.01 ± 0.07 | 311.05 ± 1.1 |
| SB234 | Bejor Ait GPS | N:22°31′37″ E:89°00′56″ | STW | 21 | 2420.01 ± 0.4 | 3.9 ± 0.08 | 197.6 ± 0.8 |
| SB235 | Chinadanga GPS | N:22°34′14″ E:88°58′32″ | STW | 21 | 1549.3 ± 0.7 | 22.01 ± 0.05 | 122.7 ± 0.04 |
| SB236 | Fulbari GPS | N:22°36′53″ E:89°00′16″ | DTW | 131 | 2270.01 ± 0.3 | 3.13 ± 0.04 | 233.7 ± 0.5 |
| SB237 | Rangashisha GPS | N:22°34′12″ E:88°04′26″ | DTW | 138 | 749.6 ± 0.08 | 4.9 ± 0.01 | 423.03 ± 0.8 |
| SB238 | Char Balitha GPS | N:22°40′07″ E:89°03′53″ | DTW | 200 | 119.7 ± 0.5 | 8.0 ± 0.4 | 285.7 ± 1.0 |
| SB239 | Kamta GPS | N:22°34′00″ E:88°59′51″ | DTW | 209 | 100.01 ± 0.4 | 9.1 ± 0.2 | 57.05 ± 0.9 |
| SB240 | Askarpur GPS | N:22°31′16″ E:89°01′52″ | STW | 27 | 129.7 ± 0.17 | 36.9 ± 0.07 | 134.7 ± 0.08 |

**Table 8**
Instrumental condition for the analysis of As and Fe.

| Metals | Wave Length (nm) | Gas flow (L/min) | Slit width (nm) | Detection limit (mg/L) | Flame type | Lamp current (mA) |
|---|---|---|---|---|---|---|
| As | 193.7 | Argon: 0.1 | 0.5 | 0.0005 | HVG | 10 |
| Fe | 248.3 | Air: 13.50, acetylene: 2.0 | 0.2 | 0.005 | Air- acetylene | 5.0 |

lowest amount of Fe content were in the TWs water of SB46 (13479.6 μg/L) and SB29 (10.01 μg/L), respectively. There is no WHO guideline for Fe in drinking water, but the BDS level of Fe in drinking water is 300–1000 μg/L. It seems that 56% TWs (28 out of 50) water, Fe content (< 1000 μg/L) was at the acceptable level of BDS guideline. The rest of 44% TWs (22 out of 50) water, Fe content was 1.1–13.5 times higher than the BDS level.

Fe content in the TWs water at Tala Upazila is shown in Table 2. The highest amount of Fe content was in the TW water of SB57 (6819.7 μg/L) and the lowest amount of Fe content was in the TW water of SB54 (30.03 μg/L). It is clear from Table 2 that 44% TWs (22 out of 50) water Fe content (< 1000 μg/L) was at the acceptable level for BDS guideline value. The 56% TWs (28 out of 50) water, Fe content was 1.05–6.8 times higher than the BDS guideline.

Table 3 represents the Fe content was in the TWs water of Assasuni Upazila. Fe content in the TWs water of SB101, SB103, SB105, SB106, SB107, SB108, SB112, SB117, SB118, SB119, SB121, SB122, and SB127 was below 300 μg/L (< 300 μg/L), which was beyond the BDS lower limit. On the other hand, in the TWs water of SB102, SB104, SB110, SB116, SB120, SB124, SB126, SB128, SB129 and SB130, Fe content was higher than the BDS higher level (> 1000 μg/L).

Fe content was in the TWs water of Kalaroa Upazila is shown in Table 4. It seems that out of 30 TWs water, only 7 TWs (SB133, SB143, SB144, SB149, SB153, SB156, and SB159) water, Fe content was at the acceptable level (300–1000 μg/L) of BDS guideline. The 43.3% TWs (13 out of 30) water, Fe content was several times higher than the BDS guideline. On the other hand, 33.3% TWs (10 out of 30) water, Fe content was below the BDS lower limit (< 300 μg/L).

Table 5 shows the Fe content in the TWs water of Kaliganj Upazila. Only in the TWs water of SB170, SB173, SB180, SB185, and SB189, Fe content was within the BDS level. In the 50% TWs (15 out of 30) water, Fe content was beyond the BDS permissible level and the 33.3% TWs (10 out of 30) water; Fe content was below the BDS lower level (< 300 μg/L).

Likewise, Fe content was in the TWs water of Shyamnagar Upazila is shown in Table 6. In the 7 (seven) TWs (SB192, SB199, SB211, SB 212, SB213, SB214, and SB219) water, Fe content was at the acceptable level of BDS guideline. In the 23.3% TWs (7 out of 30) water, Fe content was below the BDS lower limit (< 300 μg/L). The 53.3% TWs (16 out of 30) water, Fe content was several times higher than the BDS guideline.

It is clear from Table 7 that 55% TWs (11 out of 20) water of Debhata Upazila, Fe content was below the BDS lower level (< 300 μg/L). However, in the 25% TWs (5 out of 20) water, Fe content was higher than the BDS level. Only, in the TWs water of SB230, SB231, SB233, and SB237, Fe content was at the BDS level.

Most probably Fe is produced from the iron oxides, which is occurred in the groundwater with the other elements, e.g., manganese, arsenic, etc. that are typically attributed to secondary minerals in the aquifer rocks. The higher the concentration of Fe in drinking water can give an unpleasant metallic taste. The presence of higher amounts of Fe in the drinking water can affect the flavour of tea, coffee, and alcoholic beverages. Also, it can promote the growth of iron bacteria in water and also makes the water distasteful (Yagoub and Ahmed, 2009), however, no health-based guideline value for iron has been proposed (WHO, 2011).

### 3.4. Chloride content in TWs water

Chloride content in the TWs water of the seven Upazilas at Satkhira district is shown in Tables 1–7. Chloride content in the TWs water at Satkhira proper (Table 1) was ranged from 29.3 to 1968.03 mg/L. The lowest amount of chloride content in the TW water of SB24 (Katthaltala GPS) was 29.3 mg/L, and the highest amount of chloride content in the TW water of SB14 (Ramerdanga GPS) was 1968.03 mg/L. Chloride content in the drinking water for BDS is 150–600 mg/L, but there is no WHO guideline for chloride content in drinking water. It is clear from Table 1 that 40% TWs (20 out of 50) water, chloride content was at the acceptable level of BDS guideline value (150–600 mg/L). In the TWs water of SB06, SB07, SB11, SB12, SB22, SB24, SB26, SB43, SB44, SB45, SB47, and SB50, chloride content was (< 150 mg/L) below the lower limit of BDS guideline. On average, 36% TWs (18 out of 50) water, chloride content was higher than the BDS level.

Chloride content in the TWs water of Tala Upazila is shown in Table 2. The highest and the lowest amount of chloride content was in the TWs water of SB87 (2987.9 mg/L) and SB99 (38.7 mg/L),

respectively. In the TWs water of SB52, SB56, SB62, SB63, SB64, SB65, SB70, SB79, SB86, and SB97, chloride content was within the BDS guideline. On average, 60% TWs (30 out of 50) water, chloride content was higher than the BDS level. In the 20% TWs (10 out of 50) water, chloride content was below the BDS limit. In the case of chloride content in the TW water of Assasuni Upazila (Table 3), 46.7% TWs (14 out of 30) water, chloride content was within the ranged of BDS guideline but 36.7% TWs (11 out of 30) water, chloride content was above (> 600 mg/L) the BDS limit. Only, in the TWs water of SB109, SB110, SB112, SB125, and SB127, chloride content was below the BDS limit.

Table 4 shows the chloride content in the TWs water of Kalaroa Upazila. Out 30 (thirty) TWs water, only in the 6 (six) TWs (of SB140, SB149, SB152, SB154, SB155, and SB156) water, chloride content was within the BDS limit. The 47% TWs (14 out of 30) water, chloride content was higher than the BDS limit. The most stringent chloride content was in the TW water of SB137 (4324.4 mg/L), which was 7.2 times higher than the BDS higher limit. Accordingly, chloride content in the TWs water at Kaliganj Upazila is shown in Table 5. The highest and the lowest amount of chloride content were in the TWs water of SB182 (2567.6 mg/L) and SB177 (71.8 mg/L), respectively. It seems that 26.7% TWs (8 out of 30) water, chloride content was within the BDS limit but 53.3% TWs (16 out of 30) water, chloride content was beyond the BDS permissible level. In the TWs water of SB172, SB177, SB179, SB180, SB184, and SB187, chloride content was below the BDS limit.

Chloride content in the TWs water of Shaymnagar Upazila is shown in Table 6. It is clear from Table 6 that among the monitored TWs water, only in the TWs water of SB192, SB193, and SB209, chloride content was within the BDS level and in the TW water of SB194 chloride content was 52.7 mg/L, which was below the BDS level. Most of the TWs (26 out of 30) water, i.e., 86.7% TWs water, chloride content was 2.1–16.64 times higher than the BDS level. Likewise, chloride content in the TWs water at Debhata Upazilas is shown in Table 7. Only in the TWs water of SB227, and SB231, chloride content was higher than the BDS limit. The 50% TWs (10 out of 20) water, chloride content was within the BDS limit but 40% TWs (8 out of 20) water, chloride content was below the BDS permissible level. Infiltration of the seawater is one of the most reasons the presence of chloride content in the TWs water. Water contains higher chloride produces a salty taste.

In sum, 49% TWs (117 out of 240) water, As content (10.9 μg/L −167.9 μg/L) was beyond the WHO permissible level. The percentage (%) of As content was found in the TWs water at the following series: Kaliganaj (73%) > Tala (68%) > Satkhira proper (58%) > Kalaroa (53%) > Assasuni (33%) > Shymnagar (17%) > Debhata (10%). In the 17% TWs (40 out of 240) water, As content was (51.9 μg/L −167.9 μg/L) exceed the BDS permissible level. In the case of Fe, 46% TWs (110 out of 240) water, Fe content (1010.07 μg/L −8319.8 μg/L) was exceeded by the BDS limit (300–1000 μg/L). On the other hand, in the 49% TWs (118 out of 240) water, chloride content (609.8 mg/L −9987.01 mg/L) was beyond the BDS permissible level (150 mg/L −600 mg/L).

### 3.5. Human health risk assessment

#### 3.5.1. Chronic daily intake (CDI)

The calculated CDI values for the consumption of drinking water of the school going children at Satkhira district is shown in Table 9. The CDI values ranges for As of the seven Upazilas of Satkhira district were: Satkhira proper 0.047388–4.35877, Tala 0.04832–5.68048, Asasuni 0.06099–4.31654, Kalaroa 0.04691–7.87769, Kaliganj 0.04691–5.80387, Shymnagar 0.04691–7.69002 and Debhata 0.04691–1.73131 μg/kg/day, respectively. The mean values of CDI for As were ranged from 0.31060 to 1.90256 μg/kg/day. The CDI values of As were found in the series of Kaliganj > Kalaroa > Tala > Satkhira proper > Asasuni > Shymnagar > Debhata. The higher the CDI values of As may be recognized the state health risk of the school children.

#### 3.5.2. Hazard quotient (HQ)

The estimated HQ indices for As in the TW water of the investigated area at Satkhira district is shown in Table 10. The mean values of HQ of As in the TW water for Satkhira proper, Tala, Asasuni, Kalaroa, Kaliganj, Shymnagar and Debhata were: 3.47823, 5.4676, 2.8167, 5.9024, 6.34187, 1.7391 and 1.03533 μg/L, respectively. The threshold value for HQ is below 1 (HQ < 1). But, the HQ value of As for all the investigated areas was exceeded this limit and was several times higher than the threshold value of HQ. It seems that HQ is performed to understand the cumulative health risk due to consuming the As-contaminated water. Hence, school children at Satkhira district are exposed to a level of health concern.

#### 3.5.3. Carcinogenic risk (CR) of As

The CR values of As of the seven Upazilas of Satkhira district are shown in Table 11. The CR value of As was exceeded the standard value $10^{-6}$ (USEPA, 2015). It seems that the estimated values were 460–2880 times higher than the acceptable standard ($10^{-6}$). Therefore, the presence of As in drinking water may cause lifetime cancer risk to the primary school children.

### 3.6. Data comparison with standards

Table 12 shows the comparative measures between the WHO guidelines and BDS standard. As content was in the TWs water exceeds the WHO and BDS standards. In some cases, e.g., Fe and chloride levels were several times higher than the BDS level.

## 4. Conclusions

Safe drinking water is essential for the children's health. The study has provided a specific area's drinking water qualities, i.e., arsenic, iron, and chloride that are used for the primary school children. The examining activity helps the service authorities to identify the areas that need to be improved. The tube wells water arsenic, iron, and chloride levels did not follow the World Health Organization drinking water quality guidelines, or the Bangladesh drinking water quality standard. It is essential to mark the tube wells which are safe especially arsenic level or which are unsafe for use as drinking troughs. The drinking of the arsenic contaminated water, which may cause lifetime cancer risk to the primary school children. The school authorities should be wrapped in the unsafe tube wells, and fresh tube wells mounted where access to safe drinking water for the school children.

**Table 9**
CDI values for As of the school going children of primary schools, Satkhira, Bangladesh.

| Statistics | As (μg/kg/day) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Satkhira proper (n = 50) | Tala (n = 50) | Asasuni (n = 30) | Kalaroa (n = 30) | Kaliganj (n = 30) | Shymnagar (n = 30) | Debhata (n = 20) |
| Min. | 0.04739 | 0.04832 | 0.06099 | 0.04691 | 0.04691 | 0.04691 | 0.04691 |
| Max. | 4.35877 | 5.68048 | 4.31654 | 7.87769 | 5.80387 | 7.69002 | 1.73131 |
| Median | 0.70613 | 1.35595 | 0.37722 | 1.70315 | 1.67969 | 0.06099 | 0.18298 |
| Mean | 1.04347 | 1.64028 | 0.84501 | 1.77072 | 1.90256 | 0.52173 | 0.31060 |

**Table 10**
HQ values for As of the school going children of primary schools, Satkhira, Bangladesh.

| Statistics | As (μg/L) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Satkhira proper (n = 50) | Tala (n = 50) | Asasuni (n = 30) | Kalaroa (n = 30) | Kaliganj (n = 30) | Shymnagar (n = 30) | Debhata (n = 20) |
| Min. | 0.15796 | 0.161070 | 0.20330 | 0.15637 | 0.156367 | 0.15637 | 0.15637 |
| Max. | 14.52923 | 18.93493 | 14.38847 | 26.25890 | 19.346230 | 25.63340 | 5.77103 |
| Median | 2.35376 | 4.51983 | 1.25740 | 5.67717 | 5.59897 | 0.20330 | 0.60993 |
| Mean | 3.47823 | 5.46760 | 2.81670 | 5.90240 | 6.34187 | 1.73910 | 1.03533 |

**Table 11**
CR values for As of the school going children of primary schools, Satkhira, Bangladesh.

| Statistics | As (μg/L) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Satkhira proper (n = 50) | Tala (n = 50) | Asasuni (n = 30) | Kalaroa (n = 30) | Kaliganj (n = 30) | Shymnagar (n = 30) | Debhata (n = 20) |
| Min. | 7.1 E−05 | 7.2 E−05 | 9.1 E−05 | 7.0 E−05 | 7.0 E−05 | 7.0 E−05 | 7.0 E−05 |
| Max. | 6.5 E−03 | 8.5 E−03 | 6.5 E−03 | 1.2 E−02 | 8.7 E−03 | 1.1 E−02 | 2.6 E−03 |
| Median | 1.1 E−03 | 2.0 E−03 | 5.6 E−04 | 2.6 E−03 | 2.5 E−03 | 9.1 E−05 | 2.7 E−04 |
| Mean | 1.6 E−03 | 2.5 E−03 | 1.3 E−03 | 2.6 E−03 | 2.8 E−03 | 7.8 E−04 | 4.6 E−04 |

**Table 12**
Comparison between parameters of WHO and BDS.

| Parameters | This study | | Guideline | |
|---|---|---|---|---|
| | Range | Mean | WHO | Bangladesh |
| Chloride (mg/L) | 29.3–9987.01 | 1020.5 | – | 150–600 |
| As (μg/L) | 1.0–167.9 | 26.0 | 10 | 50 |
| Fe (μg/L) | 10.01–13479.6 | 1544.9 | – | 300–1000 |

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